REMARKS

By this Amendment, claims 1-30 are cancelled, and claims 31-57 are added. Thus, claims 31-57 are active in the application. Reexamination and reconsideration of the application are respectfully requested.

The specification and abstract have been carefully reviewed and revised to correct grammatical and idiomatic errors in order to aid the Examiner in further consideration of the application. The amendments to the specification and abstract are incorporated in the attached substitute specification and abstract. <u>No new matter has been added.</u>

Also attached hereto is a marked-up version of the substitute specification and abstract illustrating the changes made to the original specification and abstract.

In item 3 on page 2 of the Office Action, the Examiner indicated that the title of the invention was not descriptive. Accordingly, the Examiner required a new title of the invention which is clearly indicative of the subject matter to which the claims are directed. In response to this requirement by the Examiner, the Applicants have amended the title of the invention to be "Data Prereading Device, Data Prereading Method, and its Recording Media". The Applicants respectfully submit that the new title of the invention is clearly indicative of the subject matter to which the claims are directed. Therefore, approval of the new title of the invention is respectfully requested.

The Applicants thank the Examiner for kindly considering the references listed on the February 7, 2002 Form PTO-1449. However, in item 2 on page 2 of the Office Action, the Examiner indicated that reference "AL" (Japanese Patent Application No. 7-6088) was not considered because the February 7, 2002 Information Disclosure Statement (IDS) did not include a concise explanation of the relevance of this reference. The Examiner is respectfully reminded that, under MPEP § 609(III)(A)(3), when a reference listed on a Form PTO-1449 is in a foreign language, the requirement for providing a concise explanation of the relevance of such a reference is satisfied when the reference is listed on an English language version of a foreign search report which indicates the degree of relevance that is found by the foreign office. As

provided in MPEP § 609(III)(A)(3), the degree of relevance may be an "X", "Y", or "A" category indication on the English language version of the foreign search report.

The English language International Search Report submitted with the February 7, 2002 Information Disclosure Statement indicated that reference "AL" was an "A" category reference. Therefore, the Applicants respectfully submit that a concise statement of the relevance of reference "AL" was indeed provided to the Patent Office by the English language International Search Report under MPEP § 609(III)(A)(3). Accordingly, the Applicants respect the Examiner to consider reference "AL" listed on the February 7, 2002 Form PTO-1449. For the Examiner's convenience, a courtesy copy of each of the February 7, 2002 IDS, the International Search Report submitted therewith, and the February 7, 2002 Form PTO-1449 are submitted herewith.

The Applicants thank the Examiner for kindly indicating, in item 8 on page 8 of the Office Action, that claims 4-5, 10-11, 16-17, 19-21, 23-25 and 27-29 would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

New claim 31 includes the limitations originally presented in cancelled claims 1 and 5. New claim 32 includes the limitations originally presented in cancelled claims 2 and 4. New claim 35 includes the limitations originally presented in cancelled claims 3 and 19. New claim 38 includes the limitations originally presented in cancelled 7 and 11. New claim 39 includes the limitations originally presented in cancelled claims 8 and 10. New claim 42 includes the limitations originally presented in cancelled claims 9 and 23. New claim 45 includes the limitations originally presented in cancelled 13 and 17. New claim 46 includes the limitations originally presented in cancelled claims 14 and 16. New claim 49 includes the limitations originally presented in cancelled claims 15 and 27.

Accordingly, in view of the Examiner's assertion that claims 4-5, 10-11, 16-17, 19-21, 23-25 and 27-29 would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims, the Applicants respectfully submit that new claims 31-32, 35, 38-39, 42, 45-46 and 49, as well as new claims 33-34, 36-37, 40-41, 43-44, 47-48 and 50-51 which depend therefrom, are clearly allowable.

New claim 52 includes the limitations originally presented in cancelled claims 1 and 6. New claim 53 includes the limitations originally presented in cancelled claims 3 and 22. New claim 54 includes the limitations originally presented in cancelled claims 7 and 12. New claim 55 includes the limitations originally presented in cancelled claims 9 and 26. New claim 56 includes the limitations originally presented in cancelled claims 13 and 18. New claim 57 includes the limitations originally presented in cancelled claims 15 and 30.

In item 6 on page 3 of the Office Action, claims 1, 6-7 and 13 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Omura et al. (U.S. 5,687,347). Further, in item 7 on page 4 of the Office Action, claims 1-3, 6-9, 12-15, 18, 22, 26 and 30 were rejected under 35 U.S.C. § 103(a) as being unpatentable over Miura et al. (U.S. 5,345,560). These rejections are believed to be moot in view of the cancellation of claims 1-30. Furthermore, the Applicants respectfully submit that these rejections are inapplicable to new claims 52-57 for the following reasons.

As described beginning at line 18 on page 21 of the original specification, the left hand side of Figure 8 of the present application illustrates the storage states of the cache memory 10 when data are stored by employing the conventional storage method, and the right hand side of Figure 8 illustrates the storage states of the cache memory 10 when data are stored by employing the data storage method of the present invention.

As shown in the left hand side of Figure 8, when backward-direction preread data are stored in the cache memory by employing the conventional data storage method, the backward-direction preread data D1, D2, D3 and D4 are successively stored after the forward-direction data, i.e., in the direction along with the memory address increases. Accordingly, in the conventional data storage method, the boundary between the backward-direction preread data D1 (LBA 4700 - LBA 4799) and the backward-direction preread data D2 (LBA 4600 - LBA 4699) is LBA 4799 and LBA 4600, which results in discontinuity of data. This discontinuity will occur among all areas in the cache memory. In order to solve this problem of the conventional data storage method, it is necessary to form a cache entry, which is entry information into the cache memory, for each area of the cache memory, and to enter the formed cache entries.

However, in the data storage method of the present invention, the data in the plural prereading areas, which have been successively read in the backward direction, are controlled by the prereading startup unit so as to be successively stored in the backward-direction areas in the address space on the cache memory. That is, as shown in the right hand side of Figure 8, the backward-direction preread data D1, D2, D3 and D4 are successively stored before the forward-direction cache data.

Therefore, according to the data storage method of the present invention, data is storage is performed so that the boundary between the backward-direction preread data D1 (LBA 4700 - LBA 4799) and the backward-direction preread data D2 (LBA 4600 - LBA 4699) becomes LBA 4700 and LBA 4699, and therefore, continuity of data between the respective areas on the cache memory can be maintained.

Accordingly, as shown in Figure 10 of the present invention, the data that are stored in the cache memory can be managed by changing only the head LBA, i.e., information in the cache memory, and the head address in the cache memory, and it is not necessary to form a new cache entry for each area, which is in contrast to the conventional data storage method. Further, since the data in the plural prereading areas, which have been successively read in the backward direction, are stored in the backward-direction areas in the address space on the cache memory so that continuity of data is maintained, the data in the plural prereading areas which have been successively read in the backward direction are arranged in the cache memory by continuous addressing, and therefore, the data that is stored in the cache memory can be easily managed. Moreover, according to the data storage method of the present invention, preread data existing on the cache memory can be extracted without distinguishing between data in the forward direction and data in the backward direction when returning data in the prereading area of the cache memory to the host device.

New claims 52-53 each recite a disk memory device comprising a prereading startup unit which is operable to read, from the disk memory medium, the data to be preread which the prereading area decision unit decided is to be preread, and to store the data into the cache memory. The prereading startup unit is further recited in new claims 53-54 as being operable to

control preread data to be stored on the cache memory in the backward direction successively in front of preread data in the forward direction.

New claims 54 and 56 each recite a data prereading method comprising reading, from the disk memory medium, the data to be preread decided in the deciding of the position and size of the data to be preread, and storing the preread data in a cache memory which is a storage area for the preread data. The reading of the data is further defined in new claims 54 and 56 as storing preread data on the cache memory in the backward direction successively in front of preread data in the forward direction.

New claims 55 and 57 each recite a data prereading method comprising reading the data on the disk memory medium to be preread corresponding to the position and size decided in the deciding of the position and size of the data, and storing the preread data into a cache memory which is a storage area for the preread data. The reading of the data is further defined in new claims 55 and 57 as storing preread data on the cache memory in the backward direction successively in front of preread data in the forward direction.

Omura et al. discloses a data providing device 100 comprising an input section 101 which receives data request commands from data request sections 111, 121 of a plurality of data request devices 110, 120 over a network. The data providing device 100 includes a request-command storing section 104 which stores the data request commands by grouping the data request commands for each data request section 111, 121 of each data request device 110, 120. The data providing device 100 also includes a data generating section 102 which generates data of a predetermined size in accordance with the data request commands, a data transmitting section 103 for transmitting the data that is generated by the data generating section 102 to the data request devices 110, 120 over the network, and a request-command sequencing control section 105 for transferring the plurality of data request commands, which are stored in a request-command storing section corresponding to each data request section 111, 121, to the data generation section 102 successively at predetermined intervals of time in the order in which the request commands were received from the data request sections 111, 121 and with a predetermined proportion for the same data request section. According to the data providing

device of Omura et al., data is provided to each data request device 110, 120 so as to ensure a balance for each data request section in corresponding relationship to each data request device 110, 120, and therefore, each data request device 110, 120 can obtain the requested data from the data providing device 100 at a predetermined interval of time in the order in which the data request commands were received (see Column 4, lines 30-59, Column 7, line 48 to Column 8, line 67 and Figure 1).

However, the data providing device is not disclosed or suggested as reading, from the disk memory medium, the data which is decided to be preread, and <u>storing preread data on the cache memory in the backward direction successively in front of preread data in the forward direction</u>, as recited in new claims 52-57.

Omura et al. also discloses a file server device which comprises an auxiliary storage device 11 for storing data, prefetch fill sections 12-1 to 12-n for prefetching data from the auxiliary storage device 11, buffer sections 13-1 to 13-n for storing prefetched data, transmitting sections 14-1 to 14-n for transmitting data to terminals 19-1 to 19-n, and a request accepting section 15 for accepting data read requests which are sent from the terminals 19-1 to 19-n. The file server device of Omura et al. also comprises a displacement judging section 16 for judging, from each data request sent from the terminals 19-1 to 19-n, whether prefetching of data from the auxiliary storage device 11 should be performed or not, and for outputting a prefetch request and a data transmit request. The file server device of Omura et al. further comprises a prefetch request distributing section 17 for distributing prefetch requests to the prefetch fill sections 12-1 to12-n corresponding to the terminals, and a transmit request distributing section 18 for distributing data transmit requests to the transmitting sections 14-1 to 14-n corresponding to the terminals (see Column 4, line 65 to Column 5, line 18, Column 12, lines 3-23 and Figure 6).

In the file server device of Omura et al., prefetch judging means, which is constituted by a portion of the displacement judging section 16, judges, based on data that is requested by an immediately preceding data request or an index pointing to that data, whether data that is requested by the accepted data requested is already prefetched and stored in one of the buffer sections 13-1 to 13-n (see Column 5, lines 5-9 and Column 13, line 32 to Column 14, line 4).

When the prefetch judging means judges that the requested data has not been prefetched, request output means, which is constituted by the remaining portion of the displacement judging section 16, the prefetch request distributing section 17, and the transmit request distributing section 18, outputs a prefetch request to one of the prefetch fill sections 12-1 to 12-n corresponding to the requesting terminal to prefetch the requested data from the auxiliary storage device 11 and a transmit request to one of the transmitting sections 14-1 to 14-n corresponding to the requesting terminal to transmit the prefetched requested data to the requesting terminal. Conversely, when the prefetch judging means judges that the requested data has been prefetched, the request output means outputs a transmit request to one of the transmitting sections 14-1 to 14-n corresponding to the requesting terminal to transmit the requested data to the requesting terminal (see Column 5, lines 10-17 and Column 15, lines 11-62).

Omura et al. also discloses that when a prefetch request is received from the prefetch request distributing section 17, the prefetch fill section 12-1 to 12-n checks the corresponding buffer section 13-1 to 13-n to see if free space is available therein. If there is available space in the corresponding buffer section 13-1 to 13-n, the prefetch fill section 12-1 to 12-n prefetchs the requested data from the auxiliary storage device 11 and stores the prefetched data in the free space in the corresponding buffer section 13-1 to 13-n. The prefetch fill section 12-1 to 12-n continues to store the prefetched data according to the order in which the prefetch requests are received from the prefetch request distributing section 17 when there is still available space in the corresponding buffer section 13-1 to 13-n. However, when free space is not available in the corresponding buffer section 13-1 to 13-n, the prefetch fill section 12-1 to 12-n waits until free space becomes available in the corresponding buffer section 13-1 to 13-n (see Column 5, lines 25-35, Column 14, lines 15-37, and Figures 10 and 13).

Accordingly, Omura et al. merely discloses that the prefetch fill section 12-1 to 12-n checks the corresponding buffer section 13-1 to 13-n to determine if space is available therein, and if space is available in the corresponding buffer section 13-1 to 13-n, the prefetch fill section 12-1 to 12-n continues to prefetch data from the auxiliary storage device 11 and store the prefetched data in the corresponding buffer section 13-1 to 13-n. However, despite the

Examiner's assertion to the contrary, Omura et al. clearly does not disclose or suggest that the prefetch fill sections 12-1 to 12-n prefetch the requested data from the auxiliary storage device 11 and store the prefetched data in the corresponding buffer section 13-1 to 13-n in the backward direction successively in front of preread data in the forward direction. Instead, Omura et al. merely discloses that the prefetched data is stored in the corresponding buffer section 13-1 to 13-n by the prefetch fill sections 12-1 to 12-n according to the order in which the prefetch requests are received from the prefetch request distributing section 17 when there is available free space in the corresponding buffer section 13-1 to 13-n.

Therefore, the file server device of Omura et al. is clearly not discloses or suggested as reading, from the disk memory medium, the data which is decided to be preread, and <u>storing preread data on the cache memory in the backward direction successively in front of preread data in the forward direction</u>, as recited in new claims 52-57.

Accordingly, Omura et al. clearly does not disclose or suggest each and every limitation of new claims 52-57. Therefore, new claims 52-57 are clearly patentable over Omura et al. since Omura et al. fails to disclose or suggest each and every limitation of new claims 52-57.

Miura et al. discloses a data prefetch buffer for improving the data address hit ratio for prefetching data irrespective of whether request addresses vary in the forward or backward direction. Miura et al. discloses that a data searcher 500 uses address tags for searching for data which is stored in a buffer storage 503 and which is requested by a CPU. The CPU requests data by employing the address tags. An address estimator 501 determines an address of data which is to be prefetched next based on an address that was just previously requested and on a history of addresses of data that were already prefetched in the past. The address estimator 501 stores the previous request address so as to estimate a subsequent request address. An address generator 502 then generates as many addresses of needed data until the data from sufficient addresses succeeding or preceding the requested are address are stored, and stores the obtained data in the buffer storage 503 (see Column 4, lines 22-43).

Miura et al. also discloses that various algorithms of prereading rules (see Column 2, lines 42-68, Column 5, lines 4-35, and Column 7, line 54 to Column 8, line 3) are employed by

the address estimator 501 in order to improve the hit ratio of prefetching the data which will likely be requested by the CPU. Further, Miura et al. discloses a process of prereading data at a predetermined interval in the forward or reverse direction based on the predetermined rule (see Column 8, lines 29-61) in order to improve the hit ratio of prefetching that data which will likely be requested by the CPU.

However, similar to Omura et al., Miura et al. clearly does not disclose that prefetched data is controlled so as to be stored on the buffer storage 503 in the backward direction successively in front of prefetched data in the forward direction. Instead, Miura et al. merely prefetchs data by the predetermined interval in the forward or reverse direction based on the predetermined rule so as to improve the hit ratio of prefetching data which will likely be requested by the CPU. When a subsequent prefetch operation is performed, the newly prefetched data according to the newly predetermined interval in the forward or reverse direction is also stored on the buffer storage, which is markedly different from storing prefetched data in the backward direction successively in front of prefetched data in the forward direction.

Therefore, Miura et al. also clearly does not disclose or suggest reading, from the disk memory medium, the data which is decided to be preread, and storing preread data on the cache memory in the backward direction successively in front of preread data in the forward direction, as recited in new claims 52-57.

Accordingly, Miura et al. also clearly does not disclose or suggest each and every limitation of new claims 52-57. Therefore, new claims 52-57 are clearly patentable over Miura et al. since Miura et al. fails to disclose or suggest each and every limitation of new claims 52-57.

Furthermore, because of the clear distinctions discussed above, no obvious combination of Omura et al. and Miura et al. would result in the inventions of new claims 52-57 since Omura et al. and Miura et al., either individually or in combination, fail to disclose or suggest each and every limitation of new claims 52 and 57.

Moreover, it is submitted that the above-described distinctions are such that a person having ordinary skill in the art at the time the invention was made would not have been motivated to modify Omura et al. and Miura et al. in such a manner as to result in, or otherwise

render obvious, the present invention as recited in new claims 52-57. Therefore, it is submitted that new claims 52-57 are clearly allowable over the prior art as applied by the Examiner.

In view of the foregoing amendments and remarks, it is respectfully submitted that the present application is clearly in condition for allowance. An early notice thereof is respectfully solicited.

If, after reviewing this Amendment, the Examiner feels there are any issues remaining which must be resolved before the application can be passed to issue, it is respectfully requested that the Examiner contact the undersigned by telephone in order to resolve such issues.

A fee and a Petition for a one-month Extension of Time are filed herewith pursuant to 37 CFR § 1.136(a).

Respectfully submitted,

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DESCRIPTION

DATA PREREADING ~~DISK MEMORY~~ DEVICE, DATA PREREADING METHOD, AND ITS RECORDING MEDIA

BACKGROUND OF THE INVENTION ~~TECHNICAL FIELD~~

1. Field of the Invention

The present invention relates to a disk memory device for reading data that is recorded on a disk memory medium such as a magnetic disk, an optical disk, or the like and, more particularly, to a data prereading method for prereading data of the disk memory device.

2. Description of the Related Art ~~BACKGROUND ART~~

In order to increase the speed of reading continuously-arranged data on ~~in~~ a disk memory device, there has been employed the following ~~a~~ data prereading method. Reading ~~as follows. That is, reading~~ of a data block~~,~~ which follows a data block for which a reading request has been made~~,~~ is started, and the read data are stored in a cache memory before a next reading request is received. When ~~, and when~~ reading requests for continuous data blocks are received, the data which have been preread and stored in the cache memory are transferred, thereby performing a data transfer without being influenced by the disk rotation wait time or the reading head seek time.

As an example of such a prereading method, Japanese Published Patent Application No. Hei. 9-120617 discloses "METHOD FOR REDUCING POWER CONSUMPTION OF DISK DRIVE IN COMPUTER TO REALIZE HIGH SPEED DATA TRANSFER, AND DISK DRIVE CONNECTED WITH COMPUTER".

In the conventional prereading method, however, the direction along which the data blocks are successively arranged is assumed to be a single direction (the direction along which the logical block address increases) and, therefore, prereading of data cannot be carried out in response to an access for reading data continuously in the backward direction (the direction along which the logical block address decreases).

In recent years, a disk memory device has been increasingly used for recording/playback of video data, audio data, and the like, and the conventional method can provide effective prereading with respect to normal playback. However, when performing a trick play, e.g., a reverse playback, although the data which have already been read out and stored in the cache memory can be played backward, the data which are not stored in the cache memory must be read out successively. Further, during the reverse playback, there occurs a contradiction in that the data that are successive in the forward direction, which are not necessary, are preread, and as a result, an ~~whereby~~ improvement of data transfer by prereading cannot be achieved.

Further, during the trick play such as fast-forward

playback or fast-reverse playback, data that are sampled according to the playback speed are read out. In this case, when the conventional prereading method is employed, unnecessary data other than the required data are also stored in the cache memory and, therefore, the cache memory cannot be used effectively. Further, the interval of the required data areas is broadened as the playback speed is increased, which results ~~resulting~~ in ~~that~~ a data area that is to be requested is not present in the same track or the same cylinder. In this case, if reading of unnecessary data is performed~~carried on~~, prereading of required data cannot be made in time, thereby resulting in an interruption of the playback of video or audio.

Further, in the conventional prereading method, when the preread data are set in the cache memory, ~~since the data are stored in the direction along which the cache memory address increases in the order of the preread data,~~ the continuity of the preread data blocks that are stored in the cache memory is broken in a ~~at~~ reverse playback since the data are stored in the direction along which the cache memory address increase in the order of the preread data. Therefore, in order to secure the continuity of the preread data blocks, it is necessary to form a cache entry, which is entry information into the cache memory, for each preread data block, and to enter the cache entry into the cache list, which results ~~resulting~~ in a detriment to an efficient use of the cache memory.

Furthermore, in the playback that is based on the shuttle dial operation which enables a forward or reverse playback at a playback speed which is suited to a stop angle of a rotation dial that has been mounted on a remote controller of a video tape recorder in recent years, the playback speed can be changed in stages, and ~~it happens frequently that~~ the present playback speed is returned frequently to the previous playback speed. In this case, the data that are required in the playback at the previous playback speed cannot be preread by the method of prereading only the data that are required at the present playback speed.

Further, this problem occurs not only in the playback that is based on the above-mentioned shuttle dial operation but also in the playback that is based on the jog dial operation which enables a forward or reverse playback while changing the playback speed from frame-by-frame playback to fast playback according to the speed and direction for rotating the rotation dial.

Furthermore, when a playback start position is specified or when a still picture at a desired position in a played video is output, the playback direction may be frequently switched between the forward playback and the reverse playback by using the above-described shuttle dial operation or the jog dial operation. In this case, since the cache memory does not hold the data that are outputted from the cache memory, the data must be reread from the disk memory medium just after the switching of the playback direction, and thus, an ~~whereby~~ improvement of data transfer by

prereading cannot be expected.

The present invention is made to solve the above-described problems. An ~~and has for its~~ object of the present invention is therefore to provide a disk memory device which is able to improve data transfer by data prereading, even when a trick play, such as a reverse playback or fast a playback, is carried out.

SUMMARY ~~DISCLOSURE~~ OF THE INVENTION

According ~~As described above, according~~ to the present invention, a disk memory device comprises: a command history information storage means for holding historic information of read commands as information for reading data that are recorded on a disk memory medium, which read commands are received from a host device; a continuity detection means for detecting a direction along which prereading of data is to be carried out based~~,~~ on ~~the basis of~~ the read commands stored in the command history information storage means; a prereading area decision means for deciding the position and size of data to be preread on the disk memory medium based ~~,~~ on ~~the basis of~~ the stored read commands and the data prereading direction detected by the continuity detection means; a cache memory for holding preread data; and a prereading startup means for reading the data to be preread, which is decided by the prereading area decision means, from the disk memory medium, and for storing the data in the cache memory. Therefore, even when data are to be continuously

read out from the disk memory medium in the backward direction, i.e., in the direction along which the address decreases, prereading of these data can be carried out, and thus ~~whereby~~ continuous reading of data in the backward direction can be carried out at a high speed.

Furthermore, according to the present invention, a disk memory device comprises: a command history information storage means for holding historic information of read commands as information for reading data that are recorded on a disk memory medium, which read commands are received from a host device; a continuity detection means for detecting an area-to-area distance which is an interval of data to be preread based~~,~~ on ~~the basis of~~ the read commands stored in the command history information storage means; a prereading rule holding means for holding prereading rules for performing prereading of data; a prereading rule decision means for deciding a prereading rule to be used for prereading of data based~~,~~ on ~~the basis of~~ the read commands, the area-to-area distance detected by the continuity detection means, and the prereading rules held by the prereading rule holding means; a prereading area decision means for deciding the position and size of data to be preread on the disk memory medium based ~~,~~ on ~~the basis of~~ the prereading rule decided by the prereading rule decision means; a cache memory for holding preread data; and a prereading startup means for reading the data to be preread, which is decided by the prereading area decision means, from the

disk memory medium, and for storing the data into the cache memory. Accordingly~~Thereby~~, prereading of required data can be carried out in response to continuous read commands for data areas which are separately located at equal intervals. Therefore, even when data which are located separately at equal intervals are to be continuously read out, such as a fast playback of data that are stored on a disk memory medium, prereading of unnecessary data is avoided, and thus ~~whereby~~ the cache memory can be effectively utilized.

Furthermore, according to the present invention, a disk memory device comprises: a command history information storage means for holding historic information of read commands as information for reading data that are recorded on a disk memory medium, which read commands are received from a host device; a continuity detection means for detecting a direction along which prereading of data is to be carried out~~,~~ and an area-to-area distance which is an interval of data to be preread based ~~,~~ on ~~the basis of~~ the read commands stored in the command history information storage means; a prereading rule holding means for holding prereading rules for performing prereading of data; a prereading rule decision means for deciding a prereading rule to be used for prereading of data based~~,~~ on ~~the basis of~~ the read commands, the data prereading direction and the area-to-area distance which are detected by the continuity detection means, and the prereading rules held by the prereading rule holding

means; a prereading area decision means for deciding the position and size of data ~~to be preread~~ on the disk memory medium to be preread based~~,~~ on ~~the basis of~~ the prereading rule decided by the prereading rule decision means; a cache memory for holding preread data; and a prereading startup means for reading the data to be preread, which is decided by the prereading area decision means, from the disk memory medium, and for storing the data into the cache memory. Accordingly~~Thereby~~, prereading of required data can be carried out in response to continuous read commands for data areas which are separately located at equal intervals in the backward direction, i.e., the direction along which the address decreases. Therefore, even when data which are located separately at equal intervals in the backward direction are to be continuously read out, such as a fast-reverse playback of data that are stored on a disk memory medium, prereading of unnecessary data is avoided, and thus ~~whereby~~ the cache memory can be utilized effectively.

Furthermore, according to the present invention, in the above-described disk memory device, the prereading rule holding means holds a plurality of prereading rules. Moreover, ~~; and~~ when there are a prereading rule which is decided by the prereading rule decision means and a prereading rule which has been employed immediately before the decided prereading rule and, further, the prereading directions of these prereading rules are the same, the prereading area decision means decides the position and size of

data ~~to be preread~~ on the disk memory medium to be preread by employing both of the prereading rules in combination. Therefore, even when the data playback speed is switched from the current playback speed to the just-previous playback speed, required data have already been preread at the just-previous playback speed, and thus ~~whereby~~ the required data can be transferred to the host device without needing to reread ~~the necessity of rereading~~ the data from the disk memory medium~~,~~ after the playback speed has been switched to the just-previous speed.

Furthermore, according to the present invention, the above-described disk memory device further comprises: a cache memory pointer holding means for holding an under-transfer address indicating the position, on the cache memory, of data which is currently being transferred to the host device, and a next preread data storage start address indicating the position on the cache memory where next preread data is to be stored; and a prereading startup judgement means for judging whether or not prereading of data is to be performed so as to leave at least several blocks of data which have already been transferred to the host device, on the cache memory, by employing the under-transfer address and the next preread data storage start address which are held by the cache memory pointer holding means. Therefore, even when data playback is carried out while frequently switching the playback direction between the forward direction and the backward direction, the data which have already been transferred to the

host device just before the switching of the playback direction can be stored in the cache memory at the point of time when the playback direction is switched. Accordingly, ~~whereby~~ the already-transferred data just before the switching of the playback direction, which data are required for the playback immediately after the switching of the playback direction, can be transferred to the host device without needing to reread ~~the necessity of rereading~~ the data from the disk memory medium.

Furthermore, according to the present invention, in the above-described disk memory device, data in plural prereading areas which have been successively read out in the backward direction are stored in a backward-direction area in an address space on the cache memory so that the continuity of the data is maintained. Therefore, the data in the plural prereading areas, which have been successively read out in the backward direction, are arranged in the cache memory by continuous addressing, and thus ~~whereby~~ the data that are stored in the cache memory can be managed easily. Further, when the data in the prereading areas existing on the cache memory are returned to the host device, the data in the prereading areas existing on the cache memory can be extracted without being distinguished from the data in the forward direction.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram illustrating an example of a

construction of a disk memory device according to a first embodiment of the present invention.

Figure 2 is a flowchart illustrating an example of a fundamental process of the disk memory device according to the first embodiment of the present invention.

Figure 3 is a flowchart illustrating an example of a prereading process that is performed by the disk memory device according to the first embodiment of the present invention.

Figure 4 is a flowchart illustrating an example of a continuity detection process that is performed by the disk memory device according to the first embodiment of the present invention.

Figure 5 is a diagram illustrating an example of a data structure in a read command record table.

Figure 6 is a flowchart illustrating an example of a prereading area decision process that is performed by the disk memory device according to the first embodiment of the present invention.

Figure 7 is a diagram illustrating an example of an access area information that is stored in an access area information storage unit.

Figure 8 is a diagram illustrating an example of a data structure in a cache memory.

Figure 9 is a diagram illustrating examples of a cache list and cache entries.

Figure 10 is a diagram illustrating a state transition of

cache entries.

Figure 11 is a block diagram illustrating an example of a construction of a disk memory device according to a second embodiment of the present invention.

Figure 12 is a flowchart illustrating an example of a prereading process <u>that is performed</u> by the disk memory device according to the second embodiment of the present invention.

Figure 13 is a flowchart illustrating an example of a continuity detection process <u>that is performed</u> by the disk memory device according to the second embodiment of the present invention.

Figure 14 is a diagram illustrating an example of a data structure in a read command record table.

Figure 15 is a flowchart illustrating an example of a prereading rule decision process <u>that is performed</u> by the disk memory device according to the second embodiment of the present invention.

Figure 16 is a diagram illustrating an example of a data structure in a prereading rule table.

Figure 17 is a flowchart illustrating an example of a prereading rule pointer updation process <u>that is performed</u> by the disk memory device according to the second embodiment of the present invention.

Figure 18 is a flowchart illustrating an example of a previous rule application judgement process <u>that is performed</u> by

the disk memory device according to the second embodiment of the present invention.

Figure 19 is a flowchart illustrating an example of a prereading area decision process that is performed by the disk memory device according to the second embodiment of the present invention.

Figure 20 is a block diagram illustrating an example of a construction of a disk memory device according to a third embodiment of the present invention.

Figure 21 is a flowchart illustrating an example of a prereading process that is performed by the disk memory device according to the third embodiment of the present invention.

Figure 22 is a flowchart illustrating an example of a prereading startup judgement process that is performed by the disk memory device according to the third embodiment of the present invention.

Figure 23 is a diagram illustrating an example of a data structure in a cache memory pointer storage unit.

Figure 24 is a diagram illustrating a data structure in a cache memory.

DETAILED DESCRIPTION OF ~~BEST MODE TO EXECUTE~~ THE INVENTION

First Embodiment ~~1.~~

Hereinafter, a disk memory device according to a first embodiment of the present invention will be described with

reference to figures 1 to 10.

Figure 1 is an example of a block diagram illustrating the construction of the ~~a~~ disk memory device according to the first embodiment of the present invention. In ~~the~~ figure 1, a host device 1 outputs a read command for reading data that are recorded in a disk memory medium~~,~~ to the disk memory device.

Further, the disk memory device according to the first embodiment of the present invention comprises a host I/F unit 2, a cache hit judgement unit 3, a continuity detection unit 4, a read command history (record) table 5 as a command history information storage means, a prereading area decision unit 6, a prereading startup unit 7, a disk transfer unit 8, a head structure 9, a cache memory 10, a host transfer unit 11, a cache list 12, and an access area information storage unit 13.

The cache hit judgement unit 3 performs an inspection as to whether data corresponding to the read command, which is received from the host device 1 through the host I/F unit 2, exists on the cache memory 10 or not.

The continuity detection unit 4 calculates an access direction along which data prereading is to be carried out~~,~~ by employing the history of read commands that are stored in the read command history table 5, which is a command history information storage means.

The read command history table 5, as the ~~a~~ command history information storage means, holds the historic information of the

read commands that are transmitted from the host device 1.

As described below, the access area information storage unit 13 stores access area information relating to an access area on the disk memory medium for data that are recorded on the disk memory medium.

The prereading area decision unit 6 decides the position and size of a data area on the disk memory medium where prereading is to be carried out based ~~,~~ on ~~the basis of~~ the read command, the result of the detection by the continuity detection unit 4, and the access area information that is stored in the access area information storage unit 13.

The prereading startup unit 7 instructs the disk transfer unit 8 to read out data in the data area to be preread, which is decided by the prereading area decision unit 6, from the disk memory medium, and to store the read data in the cache memory 10.

The disk transfer unit 8 outputs the data that are read from the disk memory medium through the head structure 9~~,~~ to the cache memory 10.

The cache memory 10 holds (stores) the preread data.

The host transfer unit 11 transfers the data that are read from the disk memory medium 11~~,~~ to the host device 1 through the host I/F unit 2.

The cache list 12 holds the list of the data that are stored in the cache memory 10.

The access area information storage unit 13 holds the

access area information relating to the access area on the disk memory medium~~,~~ which was accessed at the previous prereading.

Next, the fundamental operation of the disk memory device according to the first embodiment of the present invention will be described with reference to a flowchart shown in figure 2.

Upon ~~On~~ receipt of a read command from the host device 1 through the host I/F unit 2, the cache hit judgement unit 3 searches the cache list 12 to check whether the requested data exists in ~~on~~ the cache memory 10 or not, as the fundamental process of the reading operation (step S1).

When the requested data exists in ~~on~~ the cache memory 10, the host transfer unit 11 transfers the data in ~~on~~ the cache memory 10 through the host I/F unit 2 to the host device 1 (step S3).

When the requested data does not exist in ~~on~~ the cache memory 10, the disk transfer unit 8 is instructed to read the requested data from the disk 11 through the head structure 9 onto the cache memory 10 (step S2), and ~~simultaneously,~~ the host transfer unit 11 simultaneously transfers the requested data through the host I/F unit 2 to the host device 1 (step S3).

Next, the data prereading process that is to be performed simultaneously with the above-mentioned fundamental process by the disk memory device will be described with reference to figure 3.

While executing the fundamental process which has been

described by employing the flowchart shown in figure 2, the continuity detection unit 4, which has received the read command from the host device 1 through the host I/F unit 2 and the cache hit judgement unit 3, performs a continuity detection process for calculating an access direction value indicating an access direction based ~~,~~ on ~~the basis of~~ the position of the data area which was requested by the last read command that is stored in the read command history table 5 as a command history information storage means, and the position of the data area which is requested by the present read command (step S4).

Next, the prereading area decision unit 6 performs a prereading area decision process for deciding the position and size of a data area on the disk memory medium where prereading is to be carried out based ~~,~~ on ~~the basis of~~ the position and size of the data area which is requested by the present read command, and the access direction value that is detected by the continuity detection unit 4 (step S5).

Next, the prereading startup unit 7 searches the cache list 12 to check whether data in the prereading area that is decided by the prereading area decision unit 6 exists in ~~on~~ the cache memory 10 or not (step S6).

When the data in the prereading area that is decided by the prereading area decision unit 6 does not exist in ~~on~~ the cache memory 10, the prereading startup unit 7 instructs the disk transfer unit 8 to read the data in the prereading area that is

decided by the prereading area decision unit 6, thereby performing prereading of data (step S7). After the prereading of data, the prereading startup unit 7 performs a process of updating the cache list 12 which shows the details of the data existing in the cache memory 10 (step S8).

On the other hand, when the data in the prereading area that is decided by the prereading area decision unit 6 exists on the cache memory 10, the data prereading process is ended.

The above-mentioned data prereading process, i.e., the step of deciding a prereading area and the following steps (steps S5 to S8), is repeated until a new command from the host device 1 is received, thereby continuing ~~proceeding~~ the prereading of data (step S9).

Next, the continuity detection process that is performed by the continuity detection unit 4 in step S4 shown in figure 3 will be described with reference to figures 4 and 5.

Figure 4 is a flowchart for explaining the operation of the continuity detection unit 4 of the disk memory device according to the first embodiment of the present invention, and figure 5 shows examples of read commands that are stored in the read command history table 5.

Initially, the continuity detection unit 4 performs updation of the read command history table 5. This updation is carried out as follows. In figure 5, a last read area head sector No. (number) A is set at a last-but-one read area head

sector No. C, a last read area size B is set at a last-but-one read area size D, a present read area head sector No. G is set at the last read area head sector No. A, a present read area size H is set at the last read area size B, a head sector No. of a read area corresponding to the read command that is received from the host device 1 is set at the present read area head sector No.G, a read area size corresponding to the read command that is received from the host device 1 is set at the present read area size H, and a present access direction value I is set at a last access direction value E, whereby the read command history table updation process is completed (step S11).

Next, the continuity detection unit 4 compares the present read area head sector No. G which is received from the host device 1 with the last read area head sector No. A which is updated in step S46 (step S12) so as to calculate ~~, thereby calculating~~ an access direction. At this time, the access direction is indicated by binary digits. ~~, and~~ "1" is set as the present access direction value I shown in figure 5 when the access direction is the forward direction, while "0" is set as the value I when the access direction is the backward direction (step S13 or step S14), whereby the continuity detection process is completed.

Next, the prereading area decision unit 6 decides a prereading area sector No. indicating ~~which indicates~~ a position on the disk memory medium where prereading is to be started~~,~~ and

a prereading area size which is the size of data to be preread based ~~,~~ on ~~the basis of~~ the present read area head sector No. and the present read size which are requested by the present read command, and the access direction value that is detected by the continuity detection unit 4.

Hereinafter, the prereading read decision process that is performed by the prereading area decision unit 6 in step S5 shown in figure 3 will be described with reference to figures 6 and 7.

Figure 6 is a flowchart for explaining the operation of the prereading area decision unit 6 of the disk memory device according to the first embodiment of the present invention, and figure 7 is a diagram illustrating an example of access area information that is stored in the access area information storage unit 13. In figure 7, the access area information is composed of an access area head sector No. Q which is the head sector No. of a data area on the disk memory medium where the last prereading has been performed, and an access area size R which is the size of data that is preread by the most recent ~~last~~ prereading.

In figure 6, ~~initially,~~ the prereading area decision unit 6 initially checks whether or not the prereading direction value that is detected by the continuity detection unit 4 is "1" indicating a forward-direction access (step S21).

When the prereading direction value is "1", the access area size R is added to the access area head sector No. Q so as to calculate a prereading area sector No. (step S22).

When the prereading direction value is "0" indicating an backward-direction access, the prereading area size Z is subtracted from the access area head sector No. Q so as to calculate a prereading area sector No. (step S23).

When the prereading area sector No. is calculated (step S22 or step S23), the prereading area decision unit 6 updates the access area head sector No. Q that is stored in the access information storage unit 13 to the prereading area sector No. which is presently calculated~~ this time~~, and updates the access area size R to the present read area size (step S24).

The prereading area decision unit 6 outputs the calculated prereading area sector No. and the present read area size (the prereading area size) to the prereading startup unit 7, thereby completing the prereading area decision process (step S25).

The prereading startup unit 7 searches the cache list 12 to check whether the data that is indicated by the prereading area sector No. and the prereading area size, which are outputted from the prereading area decision unit 6, exists on the cache memory 10 or not. When the corresponding data does not exist, the prereading startup unit 7 instructs the disk transfer unit 8 to read the corresponding data which is recorded on the disk memory medium and indicated by the prereading area sector No. and the prereading area size which are outputted from the prereading area decision unit 6, thereby performing prereading of data. Further, after the prereading of data, the prereading startup unit 7

performs updation of the cache list 12 so as to complete the data prereading process.

On the other hand, when the corresponding data exists, the prereading startup unit 7 performs prereading of the next data.

In this way, the area which has been accessed by the immediately preceding read command and stored in the read command history table 5 as a command history information storage means is compared with the area which is requested by the present read command, thereby deciding the direction along which prereading of the data is to be carried out. Therefore, even when the data are to be continuously read in the backward direction, i.e., the direction along which the address decreases, prereading of these data can be carried out, whereby continuous reading of the data in the backward direction can be carried out at a high speed.

Next, a method for storing the data that are read from the disk memory medium into the cache memory 10 that is performed by the disk memory device according to the first embodiment of the present invention will be described with reference to figures 8 to 10.

Figure 8 is a diagram illustrating the storage states of the cache memory 10 in the case where data are stored by employing the conventional storage method and the storage method of the present invention, respectively. As shown in figure 8, in the method of reading the data in the prereading area from the disk memory medium and storing the read data into the cache

memory 10, when the backward-direction preread data are stored in the cache memory employing the conventional data storage method, the backward-direction preread data D1, D2, D3, and D4 are successively stored after the forward-direction cache data (in the direction along which the memory address increases).

In this case, the boundary between the backward-direction preread data D1 (LBA 4700 - ~LBA 4799) and the backward-direction preread data D2 (LBA 4600 - ~LBA 4699) is LBA 4799 and LBA 4600, whereby discontinuity of data occurs. This discontinuity will occur among all areas. In order to solve this problem, in the conventional data storage method, it is necessary to form, for every area, a cache entry as shown in figure 9 which is entry information into the cache memory, and to enter the cache entries so formed.

On the other hand, in the data storage method according to the present invention, the data in the plural prereading areas, which have been successively read in the backward direction, are successively stored in the backward-direction areas in the address space on the cache memory. That is, the backward-direction preread data D1, D2, D3, and D4 are successively stored before the forward-direction cache data (the direction along which the memory address decreases).

In this case, data storage is carried out so that the boundary between the backward-direction preread data D1 (LBA 4700 - ~LBA 4799) and the backward-direction preread data D2 (LBA

4600 - LBA 4699) becomes LBA 4700 and LBA 4699, whereby the continuity of data between the respective areas can be maintained. Therefore, as shown in figure 10, the data that are stored in the cache memory 10 can be managed by changing only the head LBA (information in the cache entry) and the head address in the cache memory, and it is not necessary to form a new cache entry for every area, which is in contrast to the conventional data storage method.

As described above, since the data in the plural prereading areas, which have been successively read in the backward direction, are stored in the backward-direction areas in the address space on the cache memory so that the continuity of the data is maintained, the data in the plural prereading areas which have successively been read in the backward direction are arranged in the cache memory by continuous addressing, whereby the data stored in the cache memory can be easily managed. Further, when the data in the prereading areas which exist on the cache memory are returned to the host device 1, the data in the prereading areas which exist on the cache memory can be extracted without being distinguished from the forward-direction data ~~can be extracted~~.

Furthermore, as shown in figure 1, the processes of the cache hit judgement unit 3, the continuity detection unit 4, the prereading area decision unit 6, and the prereading startup unit 7 are performed by a CPU 101, and the read command history table

5, the cache list 12, and the access area information storage unit 13 are arranged on a RAM 100 which is readable and writable from the CPU 101.

Second Embodiment~~2.~~

Hereinafter, a disk memory device according to a second embodiment of the present invention will be described with reference to figures 11 to 20.

Figure 11 is a block diagram illustrating the construction of the ~~a~~ disk memory device according to the second embodiment of the present invention. In ~~the~~ figure 11, a host device 1 outputs a read command which instructs the disk memory device to read data that are recorded on a disk memory medium.

Further, the disk memory device according to the second embodiment of the present invention comprises a host I/F unit 2, a cache hit judgement unit 3, a continuity detection unit 16, a read command history (record) table 5 as a command history information storage means, a prereading rule decision unit 14, a prereading rule table (holding unit) 15 as a prereading rule storage means, a prereading area decision unit 17, a prereading startup unit 7, a disk transfer unit 8, a cache memory 10, a host transfer unit 11, a cache list 12, and an access area information storage unit 13.

The disk memory device according to the second embodiment of the present invention is different from the above-mentioned

first embodiment which enables prereading of a read command that requests data that are located in the backward direction (i.e., the direction along which the address decreases), in that prereading of data can be effectively performed even when the disk memory device receives continuous read commands requesting data which are located separately at equal intervals. Therefore, the constituent elements of the second embodiment ~~constituents~~ performing the same operations as those described for the first embodiment are given the same reference numerals, and descriptions thereof will be omitted.

The continuity detection unit 16 calculates an access direction along which prereading of data is to be carried out~~,~~ and an interval between areas from which data are to be read~~,~~ by employing the history of read commands that are stored in the read command history table 5 as a command history information storage means.

The prereading rule decision unit 14 decides a prereading rule that is to be used for prereading of data based~~,~~ on ~~the basis of~~ the read command, the data prereading direction and the area-to-area interval which are detected by the continuity detection unit 16, and the prereading rules that are stored in the prereading rule table 15 as a prereading rule storage means.

The prereading rule table 15, as a prereading rule storage means, holds the prereading rule which is decided by the prereading rule decision unit 14.

The prereading area decision unit 17 decides a position of an area on the disk memory medium where prereading is to be started~~,~~ and a size of the area to be preread based~~,~~ on ~~the basis of~~ the prereading rule which is decided by the prereading rule decision unit 14, and the access area information that is stored in the access area information storage unit 13.

The fundamental process of the disk memory device according to the second embodiment of the present invention is identical to the fundamental process of the disk memory device according to the first embodiment which has already been described with reference to figure 2 and, therefore, repeated description is not necessary.

The disk memory device according to the second embodiment of the present invention performs a data prereading process as follows, while executing the above-mentioned fundamental process.

Hereinafter, the data prereading process that is performed by ~~of~~ the disk memory device according to the second embodiment of the present invention will be described with reference to figure 12.

While performing the fundamental process described with reference to figure 2, the continuity detection unit 16, which has received a read command from the host device 1 through the host I/F unit 2, performs a continuity detection process for calculating an access direction and an area-to-area interval based~~,~~ on ~~the basis of~~ the position of the data area which has

been requested by the last (most recent) read command and recorded in the read command history table 5 as a command history information storage means, and the position of the data area which is requested by the present read command (step S31).

Next, the prereading rule decision unit 14 performs a prereading rule decision process for deciding a prereading rule that is to be employed for prereading of data based~~,~~ on ~~the basis of~~ the access direction and the area-to-area interval which are calculated by the continuity detection unit 16, and the data area size which is presently requested ~~this time~~ (step S32). The decided prereading rule is stored in the prereading rule table 15 as a prereading rule storage means.

The prereading area decision unit 17 decides a prereading rule that is to be applied to the prereading of data by performing a previous rule application decision process for deciding whether or not the prereading of data is to be carried out in combination with a previous prereading rule which has been employed before the prereading rule to be employed according to the present read command, and performs a prereading area decision process for deciding the position and size of a data area on the disk memory medium where prereading is to be carried out, based on ~~the basis of~~ the decided prereading rule (step S33).

Next, the prereading startup unit 7 searches the cache list 12 so as to check whether the data in the prereading area that is decided by the prereading area decision unit 17 exists in ~~on~~ the

cache memory 10 or not (step S34).

When the data in the prereading area that is decided by the prereading area decision unit 17 does not exist in ~~on~~ the cache memory 10, the prereading startup unit 7 instructs the disk transfer unit 8 to read the data in the prereading area that is decided by the prereading area decision unit 17, thereby performing prereading of data (step S35). Further, after the prereading of data, the prereading startup unit 7 performs updation of the cache list 12 so as to indicate ~~indicating~~ the details of the data that are stored in the cache memory 10 (step S36).

On the other hand, when the data in the prereading area that is decided by the prereading area decision unit 17 exists in ~~on~~ the cache memory 10, prereading of this data is completed.

The prereading area decision process in step 33 and the following processes are repeated until the disk memory device receives a new command from the host device 1, whereby prereading of data is proceeded with (step S37).

Next, the continuity detection process that is performed by the continuity detection unit 16 in step S31 shown in figure 12 will be described with reference to figures 13 and 14.

Figure 13 is a flowchart for explaining the operation of the continuity detection unit 16 of the disk memory device according to the second embodiment of the present invention, and figure 14 is a diagram illustrating examples of read commands

which are stored in the read command history table 5.

Initially, the continuity detection unit 16 performs updation of the read command history table 5 (step 541).

This updation is performed as follows. As illustrated in ~~In~~ figure 14, a last read area head sector No. A is set at a last-but-one read area head sector No. C, a last read area size B is set at a last-but-one read area size D, a present read area head sector No. G is set at the last read area head sector No. A, a present read area size H is set at the last read area size B, a head sector No. of a read area corresponding to the read command that is received from the host device 1 is set at the present read area head sector No. G, a read area size corresponding to the read command that is received from the host device 1 is set at the present read area size H, a present access direction value I is set at a last access direction value E, and a present area-to-area interval (distance) J is set at a last area-to-area interval F, thereby completing updation of the read history table 5~~(step S46)~~.

Next, the continuity detection unit 16 compares the present read area head sector No. G which is received from the host device 1 with the last read area head sector No. A which is updated in step S41 (step S42) so as to calculate ~~, thereby calculating~~ an access direction. At this time, the access direction is indicated by binary digits. ~~, and~~ "1" is set at the present access direction value I shown in figure 14 as an access

direction indicating value when the access direction is the forward direction, while "0" is set as an access direction value when the access direction is the backward direction (step S43 or step S44).

Thereafter, the continuity detection unit 16 calculates the absolute value of a difference between the present read area head sector No. G and the last read area head sector No. A, and sets the absolute value as an area-to-area interval at the present area-to-area interval J (step S45), thereby completing the continuity detection process.

Next, the prereading rule decision process that is performed by the prereading rule decision unit 14 in step S32 shown in figure 12 will be described with reference to figures 15 and 16.

Figure 15 is a flowchart for explaining the operation of the prereading rule decision unit 14 of the disk memory device according to the second embodiment of the present invention, and figure 16 is a diagram illustrating examples of prereading rules that are stored in the prereading rule table 15.

Prereading rule entries W0 to W5 constitute a group of prereading rule entries which are stored in the prereading rule table 15, and each prereading rule entry is composed of a prereading direction value X, a prereading area-to-area interval (distance) Y, and a prereading area size Z. Further, a prereading rule updation flag T is a flag indicating that the

prereading rule is updated, and this flag T indicates that the previous rule exists at the same time. It is assumed that, as a binary digit, "1" is set when the prereading rule is updated, while "0" is set when the prereading rule is not updated. A prereading rule pointer U indicates a prereading rule entry which is currently being employed.

In the flowchart of figure 15, the prereading rule decision unit 14 initially decides whether the read command, which has been supplied from the host device 1 to the disk memory device, matches the present prereading rule or not. To be specific, the prereading rule decision unit 14 decides: whether the present access direction value which is calculated in the continuity detection process (refer to steps S43 and S44 in figure 13) matches the prereading direction X of the present prereading rule which is pointed to by the prereading rule pointer U that is stored in the prereading rule table 15 (refer to figure 16) (step S51); whether the present area-to-area interval which is calculated in the continuity detection process (refer to step S45 in figure 13) matches the prereading area-to-area interval Y of the current prereading rule which is pointed to by the prereading rule pointer U that is stored in the prereading rule table 15 (refer to figure 16) (step S52); and whether the present read area size which is received from the host device 1 matches the prereading area size Z of the present prereading rule which is pointed to by the prereading rule pointer U that is stored in the

prereading rule table 15 (refer to figure 16) (step S53).

When all of these decisions (steps S51 to S53) are "match", since the present prereading rule can be applied, the present prereading rule is applied as it is~~,~~ without being changed.

On the other hand, based on the decisions (steps S51 to S53), when it is decided that the presently applied rule cannot be applied to the present read command, the last (most recent) read command is compared with the present read command so as to decide whether a new prereading rule can be decided or not.

To be specific, the prereading rule decision unit 14 decides: whether the present access direction value which is calculated in the continuity detection process (refer to steps S43 and S44 in figure 13) matches the last access direction value E which is recorded in the read command history table 5 (refer to figure 14) (step S54); whether the present area-to-area interval which is calculated in the continuity detection process (refer to step S45 in figure 13) matches the last area-to-area interval F which is recorded in the read command history table 5 (refer to figure 14) (step S55); and whether the present read area size which is received from the host device 1 matches the last read area size B which is recorded in the read command history table 5 (refer to figure 14) (step S56).

When all of these decisions (steps S54 to S56) are "match", the prereading rule pointer U in the prereading rule table 15 is updated to a new prereading rule (step S57), and the present

access direction is set at the prereading direction value X of the prereading rule entry that is pointed to by the updated prereading rule pointer U on the prereading rule table 15 (step S58), the present area-to-area interval is set at the prereading area-to-area interval Y (step S59), and the present read area size is set at the prereading area size Z (step S60), whereby the prereading rule is updated.

When the updation of the prereading rule is completed, "1" is set at the prereading rule updation flag T on the prereading rule table 15 so as to complete the prereading rule decision process (step S65).

On the other hand, based on the decisions (steps S54 to S56), when at least one of the decisions is "mismatch", since a new prereading rule cannot be applied, setting for prereading continuous data from the present read area is performed. To be specific, the prereading rule pointer U on the prereading rule table 15 is updated (step S61), and setting for prereading continuous data from the present read area is made to the prereading rule entry which is pointed to by the updated prereading rule pointer U on the prereading rule table 15. That is, the present access direction value (steps S43 and S44 in figure 13) is set at the prereading direction value X on the prereading rule table 15 (step S62), "0" is set as an area-to-area interval at the prereading area-to-area interval Y (step S63), and the present read area size is set at the prereading

area size Z (step S64), whereby the prereading rule is updated so as to complete the prereading rule decision process. In this case, updation of the prereading rule updation flag T on the prereading rule table 15 is not carried out.

Furthermore, while the prereading rule storage unit 15 of the disk memory device according to the second embodiment has five prereading entries, the present invention is not restricted thereto, and the storage unit 15 may have at least one prereading entry.

Next, the prereading rule pointer updation processes that is performed by the prereading rule decision unit 14 in steps S57 and S61 shown in figure 15 will be described with reference to figure 17.

Figure 17 is a flowchart for explaining the rule pointer updation process that is performed by the prereading rule decision unit 14 of the disk memory device according to the second embodiment of the present invention.

The prereading rule pointer updation processes in steps S57 and S61 are processes for advancing, by one entry, the prereading rule pointer which points the present prereading rule entry in the prereading rule entry group constituted like a ring buffer, and these processes are identical to each other.

In the prereading rule pointer updation process that is performed by the prereading rule decision unit 14, ~~initially,~~ the prereading rule pointer U on the prereading rule table 15 is

initially incremented by 1 (step S571).

Next, the prereading rule pointer U is compared with the maximum prereading rule entry number, which is 5 in figure 16 (step S572). When the prereading rule pointer U is larger than the maximum prereading rule entry number, "0" is set at the prereading rule pointer U (step S573).

Next, the previous rule application decision process, which is included in the prereading area decision process that is performed by the prereading area decision unit 17 in step S33 shown in figure 12, will be described with reference to figures 16 and 18.

The previous rule application decision process aims to, even when the data playback speed is changed from the present playback speed to the just-previous playback speed, perform prereading of required data at the changed playback speed, and this process enables the transfer of required data to the host device without rereading the required data from the disk memory medium after the playback speed is changed to the just-previous playback speed.

Figure 18 is a flowchart for explaining the previous rule application decision process that is performed by the prereading area decision unit 17 of the disk memory device according to the second embodiment of the present invention.

Initially, the prereading area decision unit 17 specifies a prereading rule entry which is pointed to by the prereading rule

pointer U from~~,~~ among the prereading rule entries W0-~~∼~~W5 on the prereading rule table 15 shown in figure 16 (step S71). The following description will be made on assumption that the prereading rule entry pointed by the prereading rule pointer U is W1.

Next, the prereading area decision unit 17 performs a prereading area decision process for deciding the position and size of a data area on the disk memory medium where prereading is to be carried out based~~,~~ on ~~the basis of~~ the prereading rule which is specified in step S71, i.e., a prereading direction value X_1, a prereading area-to-area interval Y_1, and a prereading area size Z_1 (step S72).

Next, the prereading area decision unit 17 decides whether or not there is a previous prereading rule which has been employed before the presently employed prereading rule and whether the prereading directions of the previous and present rules match or not, according to whether or not "1" is set at the prereading rule updation flag T on the prereading rule table 15 and whether the prereading direction value X_1 of the prereading rule entry which is pointed to by the prereading rule pointer U matches the prereading direction value X_0 of the prereading rule entry which has been recorded just before the prereading direction value X_1 (step S73).

When a previous rule exists and the prereading direction of the previous rule matches the prereading direction ~~that~~ of the

present rule, since prereading of data is carried out by employing the previous rule, a prereading rule entry which is immediately before the prereading rule entry which is pointed to by the prereading rule pointer U on the prereading rule table 15 shown in figure 16 is specified (step S74).

Next, the prereading area decision unit 17 performs a prereading area decision process for deciding the position and size of a data area on the disk memory medium where prereading is to be carried out based ~~,~~ on ~~the basis of~~ the prereading rule which is specified in step S74, i.e., the prereading direction value X_0, the prereading area-to-area interval Y_0, and the prereading area size Z_0 (step S75).

Hereinafter, the prereading area decision process that is performed by the prereading area decision unit 17 in steps S72 and S75 shown in figure 18 will be described with reference to figures 7, 16, and 19.

Figure 19 is a flowchart for explaining the prereading area decision process that is performed by the prereading area decision unit 17 of the disk memory device according to the second embodiment of the present invention, and figure 7 is a diagram illustrating an example of access area information that is stored in the access area information storage unit 13. In figure 7, the access area information is composed of an access area head sector No. Q which is a head sector No. of a data area on the disk memory medium where the last prereading has been

carried out, and an access area size R which is the size of data that are read by the last prereading.

As illustrated in ~~In~~ figure 19, the prereading area decision unit 17 decides a prereading area sector No. and a prereading area size of an area to be presently preread, based~~this time,~~ on ~~the basis of~~ the prereading direction value X, the prereading area-to-area interval Z, and the prereading area size Z shown in figure 16, which are specified in the above-described previous rule application decision process, and the access area head sector No. Q and the access area size R which are stored in the access area storage unit 13 shown in figure 7.

Initially, the prereading area decision unit 17 decides whether or not the prereading direction value X is "1" indicating an access direction in the forward direction (step S81).

When the prereading direction value is "1", the access area size R and the prereading area-to-area interval Y are added to the access area head sector No. Q so as to calculate~~, thereby calculating~~ the prereading area sector No. (step S82).

When the prereading direction value is "0" indicating an access direction in the negative direction, the prereading area size Z and the prereading area-to-area interval Y are subtracted from the access area head sector No. Q so as to calculate~~, thereby calculating~~ the prereading area sector No. (step S83).

After the prereading area sector No. is calculated (step S82 or step S83), the prereading area decision unit 17 updates

the access area head sector No. Q that is stored in the access information storage unit 13 to the prereading area sector No. which is presently calculated, ~~this time,~~ and enters the prereading area size Z at the access area size R (step S84).

The prereading area decision unit 17 outputs the calculated prereading area sector No. and the prereading area size Z to the prereading startup unit 7, thereby completing the prereading area decision process (step S85).

The prereading startup unit 7 searches the cache list 12 so as to check whether the data, which is indicated by the prereading area sector No. and the prereading area size outputted from the prereading area decision unit 17, exists in ~~on~~ the cache memory 10 or not. When the corresponding data does not exist in the cache memory 10, the prereading startup unit 7 instructs the disk transfer unit 8 to read the data that are indicated by the prereading area sector No. and the prereading area size which are outputted from the prereading area decision unit 17, thereby performing prereading of data. After the prereading, the prereading startup unit 7 updates the cache list 12 so as to complete the data prereading process.

On the other hand, when the corresponding data exists in the cache memory 10, the prereading startup unit 7 performs prereading of the next data.

Since the storage method for storing the data that are read from the disk memory medium into the cache memory 10 by the disk

memory device according to the second embodiment of the present invention is identical to the data storage method which has already been described for the first embodiment employing figures 8 to 10, a repeated description is not necessary.

As described above, the area which has been accessed by the just-previous read command which is stored in the read command history table 5 as a command history information storage means is compared with the area which is requested by the present read command, thereby deciding the direction along which prereading of data is to be carried out. Therefore, even in the case where data are to be read successively in the backward direction, i.e., the direction along which the address decreases, prereading of these data can be carried out, whereby continuous reading of these data in the backward direction can be performed at a high speed.

Further, the prereading rule is determined by detecting the continuity of the read commands, and the position and size of a prereading area where prereading of data is to be carried out is determined based on ~~the basis of~~ the prereading rule, whereby it is possible to perform prereading of data in response to continuous read commands for data areas which are separately located at equal intervals. Therefore, even when data which are located separately at equal intervals are to be continuously read, such as when data that are stored on the disk memory medium are to be played at high speed, unnecessary data are not preread, and

thus ~~whereby~~ the cache memory 10 can be utilized effectively.

Furthermore, when ~~there exist~~ the prereading rule to be employed at present and the prereading rule which has been employed immediately before the present rule exist and, further, the prereading directions of these prereading rules are the same, the position and the size of an area on the disk memory medium where prereading of data is to be carried out are determined by employing these prereading rules in combination. Therefore, even when the data playback speed is switched from the present playback speed to the just-previous playback speed, required data have already been preread at the just-previous playback speed, and thus ~~whereby~~ the required data can be transferred to the host device without rereading the data from the disk memory medium after the playback speed is switched to the just-previous playback speed.

The prereading area decision unit 17 of the disk memory device according to the second embodiment of the present invention decides whether or not prereading should be carried out by employing the previous rule in combination with the present rule. When it is decided that prereading should be carried out by employing ~~the~~ both of the rules, prereading of data is carried out by employing both of the present prereading rule corresponding to the present read command and the previous rule which has been employed just before the present prereading rule. However, the present invention is not restricted thereto, and the

prereading area decision unit 17 does ~~needs~~ not need to perform the previous rule application decision process, and therefore, prereading of data may be performed by employing only the present prereading rule corresponding to the present read command.

Further, the continuity detection unit 16 of the disk memory device according to the second embodiment of the present invention detects the data prereading direction and the area-to-area interval which is an interval of data to be preread, and prereading of data is carried out by using the result of this ~~the~~ detection based~~,~~ on ~~the basis of~~ the prereading rule which is decided by the prereading rule decision unit 14. However, the present invention is not restricted thereto. The continuity detection unit 16 may detect only the area-to-area interval which is an interval of data to be preread, and prereading of data may be carried out by using the result of this ~~the~~ detection based~~,~~ on ~~the basis of~~ the prereading rule which is decided by the prereading rule decision unit 14. Also, in this case, prereading of data can be efficiently carried out in response to continuous read commands which require data that are located separately at equal intervals.

Furthermore, as shown in figure 11, the processes of the cache hit judgement unit 3, the continuity detection unit 16, the prereading rule decision unit 14, the prereading area decision unit 17, and the prereading startup unit 7 are carried out by a CPU 103, and the read command history table 5, the cache list 12,

the access area information storage unit 13, and the prereading rule table 15 are arranged on a RAM 102 which is readable and writable from the CPU 103.

Third Embodiment ~~3.~~

Hereinafter, a disk memory device according to a third embodiment of the present invention will be described with reference to figures 20 to 23.

Figure 20 shows an example of a block diagram illustrating the construction of the ~~a~~ disk memory device according to the third embodiment of the present invention. In ~~the~~ figure 20, a host device 1 outputs a read command which instructs the disk memory device to read data that are recorded on a disk memory medium.

Further, the disk memory device according to the third embodiment of the present invention comprises a host I/F unit 2, a cache hit judgement unit 3, a continuity detection unit 16, a read command history (record) table 5 as a command history information storage means, a prereading rule decision unit 14, a prereading rule table (holding unit) 15 as a prereading rule storage means, a prereading area decision unit 17, a prereading startup unit 7, a disk transfer unit 8, a cache memory 10, a host transfer unit 11, a cache list 12, an access area information storage unit 13, a cache memory pointer storage unit 18, and a prereading startup judgement unit 19.

The disk memory device according to the third embodiment of the present invention is different from the above-mentioned second embodiment in that a protection area is provided so as to leave at least several blocks of data, which have already transferred to the upper (host) device 1, on the cache memory. Therefore, the constituent elements of the third embodiment ~~constituents~~ performing the same operations as those described for the second embodiment are given the same reference numerals, and descriptions thereof will be omitted.

The cache memory pointer storage unit 18 holds an under-sending address indicating the position on the cache memory where the data which is currently being sent to the host device is located, and a next-prereading data storage start address indicating the position on the cache memory where the next preread data is to be stored.

The prereading startup judgement unit 19 performs a prereading startup judgement process for judging whether or not the prereading of data should be carried out so as to leave at least several blocks of data, which have already been transferred to the host device, on the cache memory.

Since the fundamental processing that is performed by the disk memory device according to the third embodiment of the present invention is identical to the fundamental processing by the disk memory device according to the first embodiment which has already been described with respect to figure 2, a repeated

description is not necessary.

Next, the data prereading process that is performed by the disk memory device according to the third embodiment of the present invention will be described with reference to figure 21.

While executing the fundamental processing which has been described with reference to figure 2, the continuity detection unit 16, which has received a read command from the host device 1 through the host I/F unit 2, performs a continuity detection process for calculating an access direction and an area-to-area interval based ~~,~~ on ~~the basis of~~ the position of a data area which has been requested by the last read command which is recorded on the read command history table 5 as a command history information storage means, and the position of a data area which is requested by the present real command (step S31).

Next, the prereading rule decision unit 14 performs a prereading rule decision process for deciding a prereading rule that is to be used for prereading of data~~,~~ by using the access direction and the area-to-area interval which are calculated by the continuity detection unit 16, and the size of the data area which is presently requested ~~this time~~ (step S32). The decided prereading rule is stored in the prereading rule table 15 as a prereading rule storage means.

The prereading area decision unit 17 performs a prereading area decision process for deciding a prereading rule that is to be applied to the prereading of data~~,~~ by performing a previous

rule application judgement process for judging whether prereading of data should be carried out by employing a previous prereading rule which has been employed immediately before the prereading rule to be employed according to the present read command, and deciding the position and size of an area on the disk memory medium where prereading is to be carried out based~~,~~ on ~~the basis of~~ the decided prereading rule (step S33).

Next, the prereading startup judgement unit 19 performs a prereading startup judgement for judging whether prereading should be carried out or not by ~~,~~ employing the under-sending address and the next-prereading data storage start address which are stored in the cache memory pointer storage unit 18 (step S91).

When it is judged that prereading should not be carried out, the prereading startup unit 7 searches the cache list 12 so as to check whether the data in the prereading area which is decided by the prereading area decision unit 17 exists on the cache memory 10 or not (step S34).

When the data in the prereading area which is decided by the prereading area decision unit 17 does not exist on the cache memory 10, the prereading startup unit 7 instructs the disk transfer unit 8 to read the data in the prereading area which is decided by the prereading area decision unit 17, thereby performing prereading of the data (step S35). Further, after the prereading of the data, the prereading startup unit 7 performs updation of the cache list 12 so as to indicate ~~indicating~~ the

details of the data that are stored on ~~in~~ the cache memory 10 (step S36).

On the other hand, when the data in the prereading area which is decided by the prereading area decision unit 17 exists on the cache memory 10, the prereading of the corresponding data is ended.

The prereading area decision process in step S33 and the following processes are repeatedly carried out until the disk memory device receives a new command from the host device 1 (step S37).

The continuity detection process that is performed by the continuity detection unit 16 in step S31 shown in figure 21, the prereading rule decision process that is performed by the prereading rule decision unit 14 in step S32, and the prereading rule decision process that is performed by the prereading area decision unit 17 in step S33 are identical to those described above according to the above-described second embodiment and, therefore, descriptions thereof will be omitted.

Next, the prereading startup judgement process that is performed by the prereading startup judgement unit 19 in step S91 shown in figure 21 will be described with reference to figures 22 to 24.

Figure 22 is a flowchart for explaining the prereading startup judgement process that is performed by the prereading startup judgement unit 19 of the disk memory device according to

the third embodiment of the present invention, figure 23 is a diagram illustrating an example of a cache list which is stored in the cache memory pointer storage unit 18, and figure 24 is a diagram for explaining a protection area which is a data that are area where the data stored on ~~in~~ the cache memory 10 are protected.

With reference to figure 23, the cache memory pointer storage unit 18 holds an under-data-transfer address O indicating a cache memory address as a beginning address of a data block on the cache memory 10, which block is currently being transferred to the host device 1, and a preread data storage address P which is a cache memory address on the cache memory where the next-preread data is to be stored.

Initially, the prereading startup judgement unit 19 performs a judgement as to whether the prereading direction value X of the prereading rule entry on the prereading rule table 14, which is specified in the prereading area decision process (step S33), is "1" or not, i.e., whether prereading is to be performed in the forward direction or not (step S101).

When the prereading direction value X is "1", i.e., when prereading is to be performed in the forward direction, a predetermined protection area size is subtracted from the under-transfer address O which is the beginning address of the data block currently being transferred to the host device 1, which address is stored in the cache memory pointer storage unit 18, so

as to calculate ~~thereby calculating~~ a protection area address which is a boundary address for protecting a predetermined amount of data in the backward direction with respect to the data currently being transferred (step S102).

On the other hand, when the prereading direction value X is not "1" but "0", i.e., when prereading is to be performed in the backward direction, the prereading area size Z shown in figure 16 and the predetermined protection area size are added to the under-transfer address O so as to calculate~~, thereby calculating~~ a protection area address which is a boundary address for protecting a predetermined amount of data in the forward direction with respect to the data currently being transferred (step S103).

Next, the prereading startup judgement unit 19 judges whether or not the protection area address overlaps the area where the next preread data is to be stored, which area is determined on the basis of the next preread data storage start address P that is stored in the cache memory pointer storage unit 18, and the prereading area size Z shown in figure 16 (step S104).

When the protection area address overlaps the area where the next preread data is to be stored, prereading of data is inhibited, and the prereading startup judgement process is ended (step S105).

On the other hand, when the protection area address does not overlap the next preread data storage area, prereading of

data is permitted, and the prereading startup judgement process is ended (step S106).

When prereading of data is permitted in the prereading startup judgement process, the prereading startup unit 7 searches the cache list 12 so as to check whether the data which is indicated by the prereading area sector No. and the prereading area size which are outputted from the prereading area decision unit 17, exists on the cache memory 10 or not. When the corresponding data does not exist on the cache memory 10, the prereading startup unit 7 instructs the disk transfer unit 8 to read the data that are indicated by the prereading area sector No. and the prereading area size which are outputted from the prereading area decision unit 17, thereby performing prereading of data. Further, after the prereading of data, the prereading startup unit 7 updates the cache list 12 so as to complete the data prereading process.

On the other hand, when the corresponding data exists on the cache memory 10, the prereading startup unit 7 performs prereading of the next data.

Since the method of storing the data that are read from the disk memory medium by the disk memory device according to the third embodiment of the invention is identical to the data storage method which has been described for the first embodiment employing figures 8 to 10, a repeated description is not necessary.

As described above, prereading of data is carried out with a protection area being provided so as to leave, on the cache memory 10, at least several blocks of data which have already transferred to the host device 1, by employing the under-transfer address indicating the position on the cache memory 10 where the data being currently transferred to the host device 1 is located, and the next preread data storage start address indicating the position on the cache memory 10 where the next preread data is to be stored. Therefore, even when playback of data is carried out while frequently switching the playback direction between the forward direction and the backward direction, the data which have already been transferred to the host device 1 just before the switching of the playback direction can be stored in the cache memory 10 at the point of time when the playback direction is switched, whereby the already-transferred data just before the switching of the playback direction, which data is required for playback just after the playback direction switching, can be transferred to the host device 1 without rereading the corresponding data from the disk memory medium.

While the disk memory device according to the third embodiment of the present invention is provided with the cache memory pointer storage unit 18 and the prereading startup judgement unit 19 in addition to the construction of the disk memory device according to the second embodiment, the present invention is not restricted thereto, and the same effects as

those described above can be achieved by a disk memory device which is provided with the cache memory pointer storage unit 18 and the prereading startup decision unit 19 in addition to the construction of the disk memory device according to the first embodiment.

Furthermore, as shown in figure 20, the processes of the cache hit judgement unit 3, the continuity detection unit 16, the prereading rule decision unit 14, the prereading area decision unit 17, the prereading startup judgement unit 19, and the prereading startup unit 7 are carried out by a CPU 105, and the read command history table 5, the cache list 12, the access area information storage unit 13, the prereading rule table 15, and the cache memory pointer storage unit 18 are arranged on a RAM 104 which is readable and writable from the CPU 103.

Fourth Embodiment ~~4.~~

The disk memory devices described above for the first to third embodiments are controlled by control programs which are possessed by ROMs contained in the CPUs 101, 103, and 105 shown in figures 1, 11, and 20, respectively. The same effects as those described for the first to third embodiments can be achieved when providing these control programs through communication means such as the Internet or other networks as well as providing these control programs as being contained in various kinds of media.

Furthermore, as recording media in which the programs are to be recorded, there are, for example, floppy disk, hard disk, optical disk, magnetic disk, magneto-optical disk, CD-ROM, magnetic tape, punch card, nonvolatile memory card, etc.

APPLICABILITY IN INDUSTRY

The disk memory device according to the present invention enables the prereading of data that are recorded on a disk memory medium, such as a magnetic disk or an optical disk, in the backward direction, and efficient prereading of data which are located separately at equal intervals, thereby improving data transfer by the data prereading of the disk memory device.

ABSTRACT

Based on ~~On the basis of~~ an area which was accessed by a just-previous read command and an area which is required by a present read command, the direction of the access, the interval between the areas, and the area size are detected, and the position and size of an area on a disk memory medium where prereading of data is to be carried out are determined by using the detected values. Therefore, ~~whereby~~ prereading of data can be efficiently carried out in response to continuous read commands which request data that are located in the backward direction, i.e., the direction in which an address decreases, or data that are located separately at equal intervals.